Locked Plates Combined With Minimally Invasive Insertion Technique for the Treatment of Periprosthetic Supracondylar Femur Fractures Above a Total Knee Arthroplasty

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Objective: New locked plate devices offer theoretical advantages for the treatment of supracondylar femur fractures associated with a total knee arthroplasty (TKA). These devices also can be inserted with relative ease by using minimally invasive techniques, provide a fixed angle construct, and improve fixation in osteoporotic bone. The purpose of this study was to evaluate the results and complications of treating periprosthetic supracondylar femur fractures above a TKA with a locked plate designed for the distal femur.

Design: Prospective, consecutive case series.

Setting: Level I trauma center.

Patients/Participants: Twenty-two consecutive adult patients with 24 (2 bilateral) supracondylar femur fractures (OTA 33A) above a well-fixed non-stemmed TKA were treated with the Locking Condylar Plate. One patient who died before fracture healing and 1 who was lost to follow-up were excluded from analysis. All remaining patients (5 males, 15 females, average age, 73 (range, 50–95) years) were available for follow-up at an average of 15 (range, 6–45) months. According to the OTA classification, there were three 33A1, eight 33A2, and eleven 33A3 fractures. All fractures were closed. Indirect reduction methods without bone graft were used in all cases.

Results: Nineteen of 22 fractures healed after the index procedure (86%). All 3 patients with healing complications were insulin-dependent patients with diabetes who also were obese (body mass index >30). Two developed infected nonunions and 1 an aseptic nonunion. Postoperative alignment was satisfactory (within 5°) for 20 of 22 fractures. Fracture of screws in the proximal fragment occurred in 4 patients. In 3 of these cases, there was progressive coronal plane deformity. There was no change in alignment in any other patient. Fifteen of 17 patients who healed returned to their baseline ambulatory status, with 5 requiring additional ambulatory support compared with baseline.

Conclusions: Fixation of periprosthetic supracondylar femur fractures with a locking plate provided satisfactory results in non diabetic patients. Diabetic patients seem to be at high risk for healing complications and infection.

Key Words: periprosthetic, supracondylar femur fracture, locked plating

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The multitude of options for the treatment of periprosthetic supracondylar femur fractures associated with total knee arthroplasty (TKA) is a testament to the lack of superiority of any method. The wide metaphyseal and diaphyseal spaces and osteopenia often associated with these elderly patients can result in suboptimal internal fixation. A TKA prosthesis with a narrow or closed intracondylar space limits the diameter for a retrograde nail or completely obviates its use. Traditional plate fixation is prone to varus collapse. Blade plates or condylar screws have limited applicability for very distal fractures or when associated with a TKA prosthesis with a deep intracondylar box. Distal femoral replacement has limited longevity. New locked plate devices offer many theoretical advantages for these patients. The multiple locked distal screws provide both a fixed angle to prevent varus collapse, and the ability to address distal fractures even when associated with a TKA prosthesis with a deep intracondylar box. The provision for locked screw insertion into the diaphyseal fragment theoretically improves fixation in the often associated osteoporotic bone. These devices can be inserted with relative ease and familiarity. The purpose of this study was to evaluate the results of locked plate fixation for treatment of periprosthetic supracondylar femur fractures above a TKA.

MATERIALS AND METHODS

Twenty-two consecutive adult patients with 24 supracondylar femur fractures (2 bilateral) above a TKA treated by 2 fellowship-trained orthopaedic trauma
surgeons at a single Level I trauma center (Barnes-Jewish Hospital, St. Louis, MO) between November 1999 and April 2004 were prospectively studied. Included were patients with OTA Type 33A fractures above well-fixed, nonstemmed, total knee prostheses. Excluded were patients with a stemmed or a loose femoral component. One patient who died before fracture healing and 1 who was lost to follow-up were excluded from all analyses. Among the remaining 20 patients, there were 22 fractures (2 bilateral). Five patients were male and 15 were female with an average age of 73 (range, 50–95) years. Four patients were diabetic: 3 insulin-dependent (1 had bilateral fractures), and 1 noninsulin-dependent. Ten patients were obese (body mass index (BMI) > 30), and 3 of these were morbidly obese (BMI > 40).

Fractures

According to the OTA classification,1 there were three 33A1, eight 33A2, and eleven 33A3 fractures. All fractures were closed. Four patients also had an ipsilateral total hip arthroplasty (THA). In each of these 4 cases, the supracondylar fracture did not involve the tip of the THA stem (Vancouver type C).7 The mechanism of injury was a fall from a standing height in all cases except for 1 fall from a wheelchair.

Implants

All patients were treated with the Locking Condylar Plate (Synthes, Paoli, PA). This device has holes in the plate that are designed to accommodate nonlocking or locking screws. Eleven 6-hole, five 8-hole, three 10-hole, one 12-hole, and two 14-hole plates were used. The two 14-hole plates were used for patients with fractures between a TKA and THA prosthesis so that the plate overlapped the stem region of the THA where it was secured with 1.7-mm stainless-steel cables. For the other 2 patients with fractures between TKA and THA stems, 6-hole plates were used because the distance from the top of the plate to the tip of the THA stem was believed to be sufficient to minimize the stress riser effect between these 2 implants.

Surgical Technique

The nonlocking and locking features of the plate system were both used. Plates were not used as internal fixators (eg, LISS system) where all screws are locking screws and fracture reduction is independent of the plate contour. Instead, the plates were used in a “hybrid” mode as both reduction aids and as fixed angle devices. Plates were used as reduction aids by securing them with nonlocking screws to both the proximal fragment (average 3.4 nonlocking screws, range 2–6 screws) and distal fragment (average 1.4 nonlocking screws, range 1–3 screws). These traditional screws “lag” the plate to bone such that fracture alignment is largely dictated by the contour of the plate. On confirmation of satisfactory reduction and implant position with fluoroscopy, locking screws were inserted into the distal segment (average 3.1 locking screws, range 2–4 screws) to provide a fixed angle devise to resist varus collapse. Whenever possible, screws in the distal segment were placed across both femoral condyles. When interference with the TKA femoral component prohibited such bicondylar fixation, shorter screws solely within the lateral condyle were used. One or 2 locked screws were used in the proximal segment in 14 cases (average 1.4 locked screws, range 1–2 screws). Therefore, in 8 cases only nonlocked screws were used in the diaphysis. In all cases, indirect fracture reduction techniques were used to minimize disruption of the soft-tissue envelope surrounding the fracture site. No bone grafts or bone graft substitutes were used. All patients were treated with prophylactic perioperative antibiotics, including 1 preoperative and 2 postoperative doses of a first-generation cephalosporin. Thromboprophylaxis was with mechanical and/or chemical (warfarin or enoxaparin) methods.

Postoperative Rehabilitation

Postoperatively, patients were placed in soft dressings. Physiotherapy was initiated on the first postoperative day. Knee exercises included active (closed chain) and passive (CPM) range of motion. Toe-touch weightbearing status was used for gait and transfer training with use of a walker. Strengthening exercises and advancement of weightbearing status were initiated on evidence of progressive fracture healing.

Outcome Measures

Baseline functional data, including ambulatory status (nonambulator, home ambulator, or community ambulator) and need for assist devices, were determined during the initial hospitalization. Data for these parameters were collected again at follow-up visits. Fracture alignment was measured from immediate postoperative radiographs and compared with alignment measured from radiographs taken at follow-up visits. Changes of > 3° were considered evidence of loss of reduction whereas changes of ≤3° were considered insignificant or the result of measurement variation error. Angular alignment measurements were relative to the normal 5° of valgus of the joint line relative to the long axis of the femoral shaft. Malalignment was defined as > 5° of deformity. Rotation and leg length discrepancies were measured clinically with malalignment defined as > 10° for rotational and > 2 cm for length difference compared with the contralateral limb, respectively. Union was defined as weightbearing with no more than baseline pain levels (as some patients had painful TKAs before fracture) associated with bridging callus across the fracture site on each the anterior-posterior (AP) and lateral radiographic views. Delayed union was defined as slow progression of healing during 4 months and nonunion defined as no progression of healing during 3 months. All infections, reoperations, and other complications were recorded. Two patients who missed scheduled postoperative visits between a time when they were not yet united and when they presented with united fractures were excluded from analysis of time to union.
RESULTS

Healing

Nineteen of 22 fractures (86%) healed after the index procedure after an average clinical follow-up of 12 (range, 6–40) months (Fig. 1). The average time to union was 12 (range, 8–20) weeks. The 2 patients who were excluded from time to healing analysis missed scheduled follow-up visits at a time when fracture union was expected. In these 2 patients, fracture union was confirmed at 20 and 27 weeks, respectively. Two patients developed infected nonunions and 1 an aseptic nonunion (Table 1). The first of these 3 patients (JB) was an insulin-dependent diabetic who, at the time of fracture, had ipsilateral foot ulcers, peripheral neuropathy, peripheral vascular disease, and obesity (BMI > 30). Also, in retrospect, this patient may have had a pre-existing infection related to his TKA that led to the infection of the fracture site. The TKA procedure, performed at another institution 4 months before fracture, was complicated by prolonged wound drainage that resolved with oral antibiotic treatment. He had persistent pain and swelling of the knee and radiographs showed lucency of the medial femoral condyle that may have represented underlying osteomyelitis. This patient was ultimately treated with an above-knee amputation.

The other patient with an infected nonunion (VB) also was an insulin-dependent diabetic who presented with bilateral chronic heel ulcers, peripheral neuropathy, peripheral vascular disease, previous stroke (residual contralateral lower extremity weakness), obesity (BMI > 30), and a mechanical heart value that required intravenous (IV) heparin anticoagulation after fracture repair. He developed chronic osteomyelitis at this fracture site despite multiple surgical débridements and IV antibiotic therapy. This patient refused the recommended above-knee amputation, is currently 6 months from the index procedure without change in his malalignment, and is being treated with a plan for salvage knee fusion.

The third patient with a healing complication had bilateral fractures and also was an insulin-dependent diabetic with peripheral neuropathy and morbid obesity (BMI = 64). The left-sided fracture (DM-L) healed uneventfully. The right sided fracture (DM-R) developed an aseptic nonunion associated with fracture of proximal screws and progression from 2° valgus postoperatively to 9° valgus at the most recent follow-up (17 months). She has declined operative repair of the nonunion.

Functional Outcome

The average time to unrestricted weightbearing was 12 (range, 8–20) weeks for the patients without fixation failure and 14 (range, 10–18) weeks for those with fixation failure. At baseline, 15 patients were community ambulators, 3 household ambulators, and 2 were nonambulators. Nine patients required no assist devises, 4 required a cane, 5 a walker, and 2 a wheelchair at baseline. The 3 patients with healing complications each deteriorated to nonambulators (2 were previous household ambulators with a walker and 1 a community ambulator with a walker). Among the 17 patients who healed their fracture, 15 returned to their baseline ambulatory status and 2 changed from community to household ambulatory status. Six of these 17 patients required additional ambulatory support compared with baseline. Four who used no assist devises at baseline required an assist device at follow-up: 3 a walker and 1 a cane. One patient who required a cane at baseline needed a walker at follow-up.

Other Complications

Fracture of screws in the proximal fragment occurred in 4 patients (Table 1). Among the 8 fractures where only nonlocking screws were used in the proximal fragment, 3 had screw failure. There was only 1 case with fracture of proximal screws among the 14 patients treated with locking screws to supplement fixation in the diaphyseal fragment. There were no distal screw failures and no plate failures. In 3 of 4 cases with fracture of proximal screws, there was progressive deformity in the coronal plane. In 1 of these cases (ES), there was a change from 1° valgus immediately postoperative to 6° varus at

union (18 weeks). There was no further change in alignment noted at the last follow-up at 92 weeks. In the second such case (KW), there was a change from 2° valgus immediately postoperative to 9° valgus at union (10.4 weeks; Fig. 2). There was no further change in alignment noted at 48 weeks. Neither of these patients required additional treatment, and both had satisfactory outcomes with both returning to their baseline ambulatory status. The third patient with progressive coronal plane deformity was the diabetic patient (DM-R) with aseptic nonunion whose course has been described above. The fourth patient with fracture of proximal screws (NM) was noted to have 2 fractured screws in the proximal fragment at union (20 weeks) and was without change in alignment at 191 weeks compared with immediately postoperative. There was no change in fracture alignment in any other patient. There was no evidence of progressive loss of alignment related to distal fragment fixation in any case. Two patients had immediate postsurgical malalignment of their fractures (DB and JM), 7 valgus and 13 valgus, respectively.

**DISCUSSION**

Treatment of patients with supracondylar femur fractures associated with TKA prostheses presents unique challenges. Nonoperative treatment has been associated with poor results for displaced fractures, especially relative to results of operative fixation. These fractures often occur in elderly patients with osteoporotic bone making stable fixation difficult. The presence of the TKA prosthesis can complicate treatment of these fractures by interfering with or precluding the use of standard fixation methods. The current study indicates that new locked plate devices reduce some of the complications seen with traditional fixation methods.

Plate fixation of supracondylar femur fractures with traditional condylar buttress-type plates are prone to complications. When comminution is present, these nonfixed-angle implants are especially prone to varus collapse. Davison reported >5° of collapse to occur in 11 of 26 (42%) such comminuted distal femur fractures. These problems can be magnified in patients with fractures associated with a TKA because these patients often are elderly with osteoporotic bone making stable internal fixation unreliable. This is confounded by the reduced ability to gain bicondylar screw purchase because of interference of the TKA prosthesis. Figgie et al. reported failure of internal fixation in 5 of 10 patients with periprosthetic femur fractures above a TKA treated with traditional plating methods, and Merkel and Johnson reported satisfactory results in only 3 of 5 such patients. Traditional fixed angle plate constructs, such as 95° condylar plates and blade plates, reduce the risk for varus collapse, but have limited application for fractures about a TKA prosthesis because of interference with the femoral component. For these reasons, it has been suggested that (nonlocked) plate fixation of these fractures should be reserved for patients who do not have osteopenia and in whom stable fixation can be achieved. Unfortunately, preoperative identification of this subset can be difficult or impossible.

Retrograde intramedullary nailing has evolved as a satisfactory treatment option for fixation for supracondylar femur fractures that are not associated with total knee arthroplasty. This fixation method is advantageous.

### TABLE 1. Summary of Results

<table>
<thead>
<tr>
<th>Patient Initials</th>
<th>AO/OTA</th>
<th>Postoperative Alignment</th>
<th>FU Alignment</th>
<th>Healed</th>
<th>Diabetic Status</th>
<th>Complications</th>
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<tbody>
<tr>
<td>NM</td>
<td>33A3</td>
<td>1 valgus</td>
<td>NC</td>
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<td>No</td>
<td>Proximal screw fracture</td>
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<td>DW</td>
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<td>NC</td>
<td>Y</td>
<td>No</td>
<td>Proximal screw failure, varus collapse</td>
</tr>
<tr>
<td>ES</td>
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<td>2 varus</td>
<td>NC</td>
<td>Y</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>DW</td>
<td>33A3</td>
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<td>NC</td>
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<td></td>
</tr>
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<td>6 varus</td>
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<td></td>
</tr>
<tr>
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<td>33A2</td>
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<tr>
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<td>NC</td>
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</tr>
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</tr>
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<td>33A2</td>
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<tr>
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<td>9 valgus</td>
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<td>No</td>
<td>Proximal screw fracture, valgus collapse</td>
</tr>
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<td>DB</td>
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<td>Y</td>
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<td></td>
</tr>
<tr>
<td>JM</td>
<td>33A1</td>
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<tr>
<td>DM-R</td>
<td>33A3</td>
<td>2 valgus</td>
<td>9 valgus</td>
<td>N</td>
<td>IDDM</td>
<td>Proximal screw fracture, nonunion, valgus collapse</td>
</tr>
<tr>
<td>GM</td>
<td>33A2</td>
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<td>NC</td>
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</tr>
<tr>
<td>KH</td>
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<td>Y</td>
<td>NIDDM</td>
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<td>DO-R</td>
<td>33A2</td>
<td>5 valgus</td>
<td>NC</td>
<td>Y</td>
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<td></td>
</tr>
<tr>
<td>LH</td>
<td>33A3</td>
<td>4 varus</td>
<td>NC</td>
<td>Y</td>
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<td></td>
</tr>
<tr>
<td>JB</td>
<td>33A3</td>
<td>3 varus</td>
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<td>NA (AKA)</td>
<td>IDDM</td>
<td>Osteomyelitis, AKA</td>
</tr>
<tr>
<td>VB</td>
<td>33A3</td>
<td>1 valgus</td>
<td>NC</td>
<td>N</td>
<td>IDDM</td>
<td>Osteomyelitis, declined AKA</td>
</tr>
<tr>
<td>DO-L</td>
<td>33A2</td>
<td>5 valgus</td>
<td>NC</td>
<td>Y</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>DM-L</td>
<td>33A1</td>
<td>neutral</td>
<td>NC</td>
<td>Y</td>
<td>IDDM</td>
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</tr>
</tbody>
</table>

NC, no change from postoperative alignment.
because of the indirect nature of the fracture reduction and associated minimization of soft tissue disruption about the fracture. However, problems obtaining stable fixation with intramedullary nails in patients with wide metaphyseal areas, with osteopenia, or both can lead to loss of fixation and malalignment. When a TKA is present, the potential difficulties of retrograde nailing of supracondylar femur fractures are increased. Some TKA designs, because of a closed or narrow intercondylar notch, preclude the use of retrograde nails or limit their maximum diameter, respectively. Furthermore, the specific prosthesis type may be unknown at the time of fracture fixation. In these cases, the choice of an anterior surgical approach used for retrograde nailing may need to be aborted in favor of a lateral approach for plate fixation if a nonaccommodating prosthesis is encountered.

Plates designed for placement along the distal lateral femur with the capacity for locking screws have potential advantages for the fixation of supracondylar femur fractures associated with TKA. In contrast to traditional 95° plate devices, locking plates offer multiple distal locked screw options. This provides for multiple fixed angle points of fixation in the distal fragment. In each of the cases in the current study, at least 2 such screws were able to be placed across to the medial condyle despite the presence of a TKA femoral component. When the TKA blocked bicondylar fixation, unicondylar locked screws were used. This combination of bicondylar and unicondylar locked screw fixation provided excellent distal fixation because no distal fixation failures occurred in the current series. These results are consistent with those of other locking plate devices. In the current study, screw failure in the proximal fragment occurred in 4 cases (18%). Because the average time to unrestricted weightbearing was slightly greater in the 4 patients with fixation failure (compared with those without fixation failure), this factor is unlikely to be causative.

These results also are consistent with those of other locking plate devices where plate or proximal screw failure is reported to occur in 13% to 18% of cases. Three of 4 failures occurred when exclusively nonlocking screws were used in the shaft fragment (3 of 8 cases,

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38%). Only 1 such failure occurred among the 14 cases where locking screws supplemented nonlocked fixation in the shaft. This failure occurred in a patient with diabetes and obesity who developed an aseptic nonunion. Biomechanical investigations suggest that locked screws in the diaphysis may protect from this type of screw failure, especially in osteoporotic bone. The precise reason for these failures and for the protective effect of the locking screws is uncertain. However, we hypothesize that the axial and varus moment forces about the distal femur get concentrated at the most proximal screw at or near the bone–plate interface. After cyclic loading and unloading, such as that associated with range of motion exercises, it is possible that slight sequential loosening of nonlocking screws in the shaft could occur, especially in the presence of osteoporotic bone. With such loosening, more and more of the varus stresses would become concentrated at the most proximal screws leading to their failure at the bone–plate interface. Locked screws would protect the construct from such failure on 2 accounts. First, the locking nature of the screws minimizes the risk of loosening and would be independent of the strength of the bone. Second, the locking screw(s) would have to cut longitudinally through the diaphyseal cortex (simultaneously when >1 are present) to fail. Based on the paucity of such failures in this series, it seems plausible that even osteoporotic bone is able to resist such cutout of locked screws.

A “hybrid” plating technique that combined the use of nonlocked and locked screws was used in the present series. Inserting nonlocked screws, before locked screws in any given fragment, allows the plate to be used as a reduction aid where the contour of the plate helps dictate the reduction in the coronal plane. Malreductions were present in 2 of 22 cases (9%). This compares favorably with the malreduction rate (6–20%) reported with internal fixator systems (such as LISS) where reduction is independent of plate contour. 13,15,19,20

Despite the serious complications that occurred in 3 patients, we believe that the results of this study support the use of locked plating using hybrid technique for the treatment of supracondylar femur fractures above a TKA. The 3 patients with healing complications were at exceedingly high risk for complications. All had insulin-dependent diabetes mellitus, neuropathy, and obesity as associated comorbidities. The 2 who developed infectious complications each also had pre-existing infectious conditions that may have contributed to their osteomyelitis. Both had chronic diabetic foot ulcers that may have seeded their fracture site and 1 also had a history suspicious for pre-existing infection related to their TKA. Among the other 17 patients (all nondiabetic), all healed after the index procedure despite the absence of bone grafting. The average time to union, 11.7 weeks, was comparable to other methods of indirect fracture fixation for such fractures.

In conclusion, we found that fixation of supracondylar femur fractures associated with stable nonstemmed total knee arthroplasty with a locking plate designed for the distal femur yielded satisfactory results. Use of such plates in “hybrid” mode provides the advantage of using the plate as a reduction aid (familiar to most surgeons) to help acquire satisfactory reduction and the ability to use the plate as a fixed angle devise. Healing was reliable and timely in all nondiabetic patients. Diabetic patients seem to be at high risk for healing complications and infection (especially when chronic foot ulcers are present). Locking screws placed in the diaphyseal fragment to supplement nonlocked fixation seem to reduce the risk of proximal screw failure.

REFERENCES
